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GB A 2116403 **GB A 2039447**
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H4M
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(54) **Communications systems**

(57) Data from a primary data source S_1 is encoded using a redundant code and further data from a source S_2 is selectively introduced when channel interference conditions permit by adding modulo 2 in an adder 10 to some of the bits or symbols of the output code word derived from the encoded data from source S_1, or by substitution (Fig. 2). At the receiver decoder (14), the data S_1 is recovered and an error string is generated each bit of which indicates the presence or absence of an error in each bit or symbol of the received data. The bits of the error string corresponding to those bits or symbols which were modified to introduce the further data from the source S_2 correspond to the recovered data S_2^1. The combined data from sources S_1 and S_2 may be subject to encoding (4) and decoding (8) at either end of the channel (6).

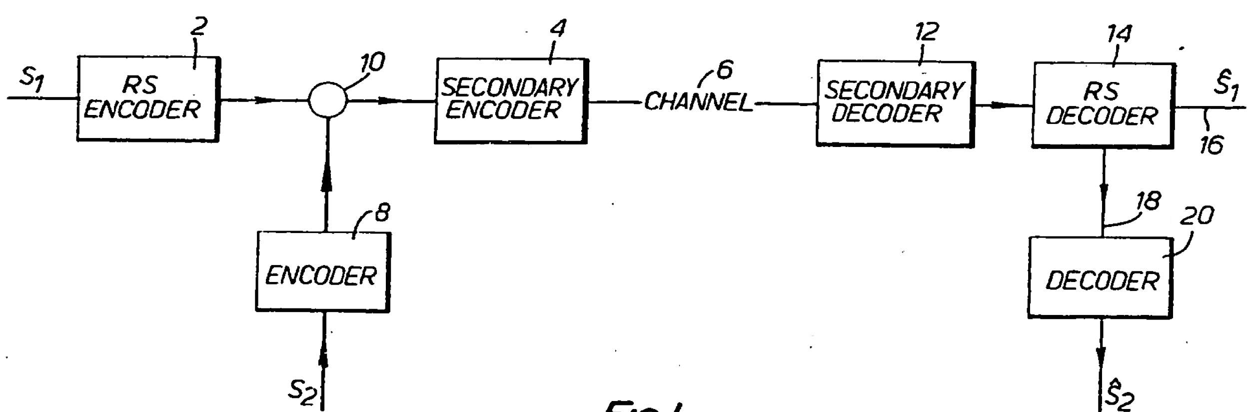

FIG. 1.

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The drawings originally filed were informal and the print here reproduced is taken from later filed formal copies.
The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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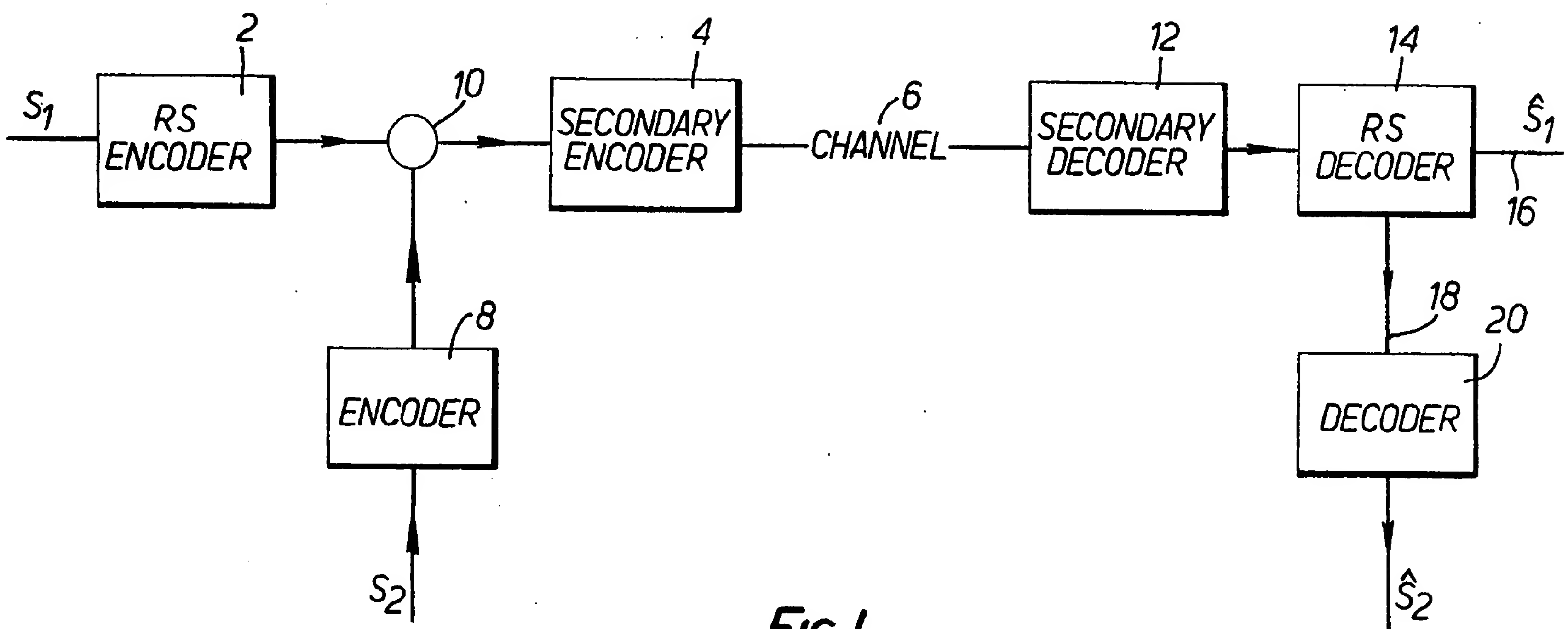

FIG. 1.

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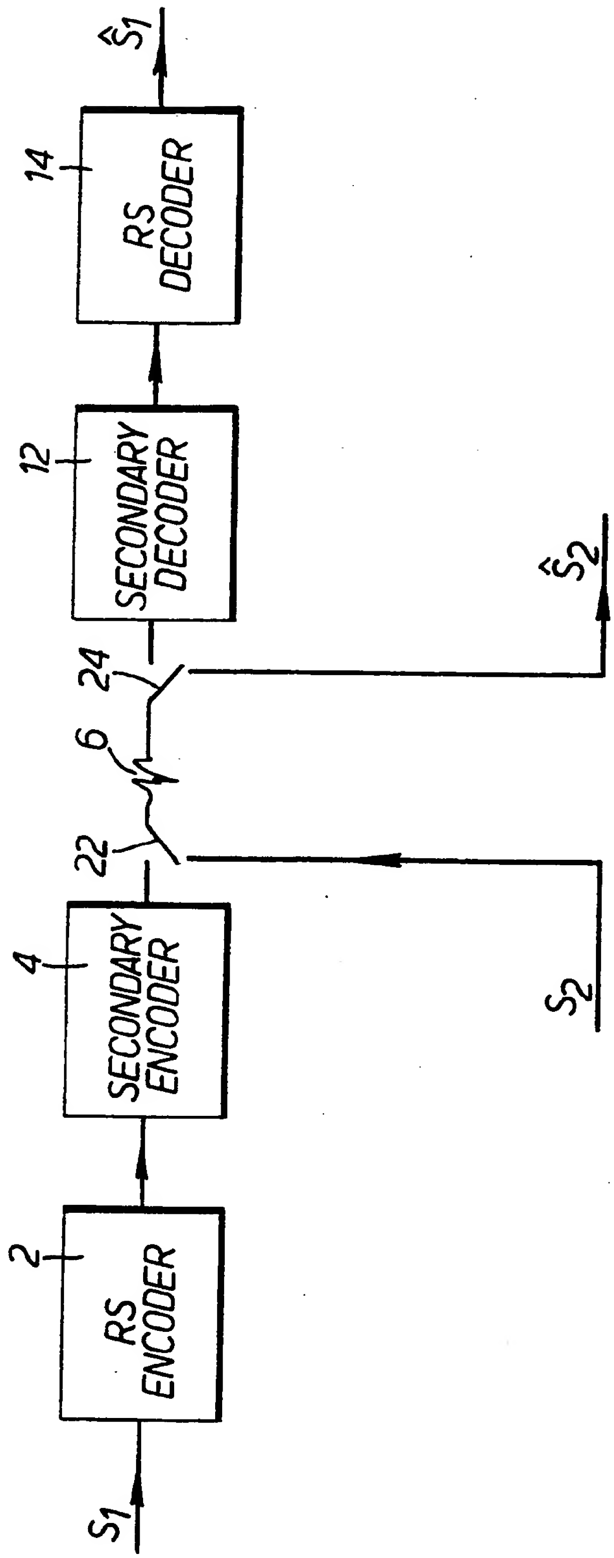

FIG. 2.

SPECIFICATION
Communications Systems

The present invention relates to communications systems and, in particular, to communications systems which are subject to varying types of interference, either arising from natural causes such as multipath effects or fading or due to the presence of jammers.

In order to provide high reliability communications over a channel subject to a relatively high degree of interference, it is known to encode the data using a redundant code which allows errors to be corrected at the receiver at the expense of reducing the data rate of the communications channel. For example, a coding system arranged to provide high reliability communications and the ability to correct a relatively large proportion of errors may have a data rate of a 1/4 or less. That is only a quarter of the bits transmitted represent information bits from the message to be transmitted, whilst the remainder are redundant bits which enable errors in the received data to be corrected.

A simple but inefficient form of redundant coding is Majority Voting, where each information bit is transmitted an odd number of times. The received block of bits is then decoded as either a 0 or a 1 in dependence on whether the majority of the received bits in the block are 0's or 1's. Such an encoding system is highly redundant but is only capable of detecting a relatively small number of errors and is moreover liable to produce undetected incorrect decoding. More efficient redundant codes include Hamming codes, Reed-Muller codes and Reed-Solomon codes. The first two of these codes operate on individual bits of data whereas the Reed-Solomon (RS) code is a symbol code and operates on symbols where each symbol is made up of a number of bits, typically 5 or 8 in practical situations.

A most efficient form of coding involves the concatenation of two codes. For example the data is first encoded using a RS code and then each symbol of the encoded data is itself encoded using a secondary code such as, for example, a Reed-Muller (RM) or Hamming code. The use of such concatenated coding is advantageous because the received, possibly corrupted, data is first processed by the secondary decoder 12, such as an RM or Hamming decoder. This decoder will correct for low levels of interference. Faced with high levels of interference the secondary decoder will, with high probability, proclaim the affected symbol to be an erasure, that is unreliable. On some occasions the secondary decoder will fail either to correct the symbol or proclaim it as corrupt, that is produce an erroneous symbol. Therefore the Reed-Solomon decoder will receive an input consisting mainly of good symbols, a minority of erased symbols and a very rare occurrence of erroneous symbols. This is precisely the form of input RS decoders are optimal at handling.

Whilst the use of a highly redundant code will ensure that the transmitted data is correctly decoded when the channel is subject to interference, the data rate is generally low and in some circumstances the interference on the communications channel is not so severe as to require the entire error correcting capability of the coding system.

The present invention therefore is directed towards solving the problem of making the most efficient use of a communications channel as regards the transmission of information through it under varying conditions of interference.

The present invention accordingly provides a communications system using a redundant code to encode and transmit data from a first source in blocks of data, and means for selectively multiplexing a proportion of data from a second source with each block of the encoded data from the first source, said proportion being less than the proportion of redundant data added to each block by the redundant coding.

More specifically the invention provides a communications system comprising a transmitter comprising an encoder for encoding digital data to be transmitted from a first source by means of a redundant code, means for selectively modifying predetermined bits or symbol positions of the blocks of encoded data output from the encoder in dependence on optionally encoded data from a second source to be transmitted, the number of bits from the second source being less than the number of redundant bits or symbols introduced by the encoder, and means for thereafter transmitting the encoded data blocks, and a receiver comprising means for separating the data from the first and second sources.

Using this method of communications it is possible to add in the further data when the interference on the communications channel is relatively low or high integrity of the data from the first source is not required. The further data can be readily switched out when the system is subject to considerable interference or it is necessary to ensure that the primary data has a high reliability.

In one embodiment the selective modifying means comprises means for adding modulo 2 bits of optionally encoded data from the second source to bits of encoded data from the first source. In such an embodiment the separating means preferably comprises a decoder for outputting the decoded and corrected data from the first source and an error string of bits which are each set in dependence on whether there is an error in an associated bit or symbol in the received data block, and means for deriving from the bits of said error string corresponding to said predetermined bit or symbol positions the data transmitted from the second source.

In another embodiment the optionally encoded data from the second source is substituted for predetermined bits or symbols of encoded data from the first source.

Preferably the modified encoded data is further encoded prior to transmission to give error protection to the data from both sources.

An embodiment of the invention will now be

described, by way of example only, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a schematic block diagram of a first communications system embodying the present invention; and

Figure 2 is a schematic block diagram of a second communications system.

A primary data source S_1 produces a stream of digital data bits. This data stream is encoded in a first encoder 2. The encoder 2 may, for example, be a (31, 15) RS encoder, which operates on symbols of five bits each. The data to be encoded is divided into five bit symbols and 15 such data symbols are encoded into a data block or code word of 31 five-bit symbols. Such an RS code has a data rate of approximately 0.48. Other types of more or less redundant RS codes may also be used in dependence upon the amount of error correction capability required.

RS codes and their properties are described in detail in a paper by their originators, I.S. Reed and G. Solomon entitled "Polynominal codes over certain finite fields" J. Soc. Ind. Applied Maths, volume 8 pages 300 to 304, June 1960. Reed-Solomon encoders and decoders are manufactured by such companies as Cyclotomics Inc of the United States of America.

RS codes can be used with varying degrees of redundancy but, clearly, the number of symbol errors or erasures that can be corrected by a given code depends on the number of redundant symbols introduced by the code. An erasure is a symbol that is known by the decoder to be unreliable whereas an error is an incorrect symbol, the location of which is not known. For an RS code, if the number of errors equals S and the number of erasures equals T, then the received code word can be fully corrected provided 2S+T is less than or equal to the number of redundant symbols in the code word. Therefore the maximum value of 2S+T for a (31, 15) RS code is 31−15, that is 16.

The encoded symbols produced by the RS encoder 2 are then coded by a secondary encoder 4, which is for example a (16, 5) RM encoder. The RM encoder 4 takes each of the 31 5 bit symbols and redundantly encodes each of them into a 16 bit symbol. The combination of two levels of coding is called concatenation and is known to be a highly effective way of protecting data as discussed above.

In many circumstances the channel 6 over which the data is to be transmitted is such that 2S+T is significantly less than the number of redundant symbols, in the present example 16. In these cases it is possible to introduce further data to be transmitted from a second source S_2 to modify the encoded data in such a fashion that the number of erased symbols is slightly increased and the integrity of the data transmitted from the primary source S_1 is not significantly endangered. That is the new 2S+T is still with high probability less than the number of redundant symbols. There are several possible ways of introducing this additional data from the secondary source S_2.

In the system illustrated in Figure 1 the data from the secondary source S_2 is first encoded by encoder 8 which produces an output in 5 bit symbols. A predetermined number of these 5 bit symbols is added to a corresponding number of the 5 bit symbols output from the RS encoder 2 in each 31 symbol codeword. For example 10 5 bit symbols from the encoder 8 are added modulo two in an adder indicated at 10 to say the first ten symbols of a codeword output from encoder 2. The 31 5 bit symbols (which now form an uncorrupted RS codeword if and only if the data from the secondary source was all zero) are then fed to a secondary encoder 4. The data output from the encoder 4 is then fed to a transmitter (not shown) where it is suitably modulated and transmitted over the channel 6 to a receiver (not shown). The data may be corrupted during the course of transmission.

The encoder 8 is optional, but may be any suitable type of encoder. Preferably, the output code word of 5 bit symbols is of low redundancy as the channel is assumed to be reasonably error-free when this additional data is being transmitted. The encoder 8 may utilise a code such as a Reed-Solomon, Hamming or Reed-Muller code or Majority Voting, so as to produce data which is in the form of 5 bit symbols or may effectively be divided into 5 bit symbols. It will be noted that the illustrated arrangement of encoders provides data protection by concatenated codes for data from both sources.

The transmitter and receiver may each form part of a conventional radio or a frequency-hopping radio operating in the HF, VHF or UHF band. Any suitable modulation technique may be employed such as amplitude modulation, frequency or phase shift keying.

The received data blocks are first decoded by a secondary decoder 12 which decodes the code applied to the transmitted data by encoder 4. The decoder 12 decodes 16 bit symbols to 5 bit symbols. All the data from both the first and second sources is afforded the protection offered by the code applied by encoder 4 and decoded by the decoder 12. The output from decoder 12 is fed to a further decoder 14 which decodes the RS code applied by encoder 2. When additional data from the second source has been added modulo 2 into the primary data the RS decoder 14 will declare the first ten symbols of each codeword to be unreliable. This is because the addition of the secondary symbols has erased the RS structure in these positions. The decoder 14 then proceeds to work out the true original value of the data and an error string which indicates the errors in the erased and erroneous symbols. In the case of the first ten symbols the modulo 2 addition will cause there to be errors in bit positions where a 1 is transmitted and no error where a zero is transmitted. Therefore, the error string for the first ten symbol positions is identical to the data added from the encoder, if there has been no further corruption during transmission. Therefore the decoder corresponds respectively to the true original data from the primary data source S_1 and the values of all the corrupting data, i.e. the encoded data from secondary source S_2 plus any other digital noise that was not already corrected by decoder 14.

The original data from the first source is output along line 16 and the corrupting data along line 18 to a decoder 20 which decodes the code applied by the encoder 8 to the data from the second data source S_2. This decoder has the effect of removing at least some of the errors caused by the previously uncorrected digital noise.

The described system takes advantage of the ability of the RS decoder 14 to proclaim erased symbols in order to detect those symbols which have been modified by the data from the second source. It is further possible to identify the secondary data by prefacing it with some clearly identifiable indicating stream. For instance the presence of secondary data could be indicated by adding 5 all one 5 bit symbols onto the RS code word. The RS decoder 14 will correct these symbols and the error string output at line 18 could be monitored for this preamble.

It will be seen that the degree of error protection afforded to the data from the first source is restricted when secondary data is added. However this data is still protected. When 10 symbols of each code word are modified by the secondary data the protection afforded to the primary data is equivalent to the use of a (21, 15) truncated RS code on 5 bit symbols concatenated with the (16, 5) RM code.

The modified system shown in Figure 2 is essentially similar to the system of Figure 1 and corresponding parts have been given like reference numerals. However in this system the data from the secondary data source is not encoded before being added to the encoded primary data. Further the secondary data is substituted, rather than added modulo 2 as in the previous embodiment, as 16 bit symbols for a predetermined number of the 16 bit symbols output from the encoder 4. For example the first 10 symbols of each of the 31 encoded symbols of an RS code word may be replaced by 160 bits of data from the secondary source S_2 by means of a time controlled switch means 22. At the receiver the secondary data is switched directly out by switch means 24 which are synchronised with switch means 22 so that the substituted 160 bits are fed out from each code word received. It will be appreciated therefore that this system provides no error protection whatsoever to the secondary data.

The data rate of the system for data transmitted from the second source has been improved in the Figure 2 system over that provided by the Figure 1 system as is illustrated in the table below which assumes that in both systems the encoder 2 uses a (31, 15) RS code and the encoder 4 uses a (16, 5) RM code. In the system of Figure 1 the encoder 8 is assumed to use a (16, 5) RS code.

	Fig. 1 System	Fig. 2 System
Primary data rate	0.151	0.151
Secondary data rate	0.100	0.322
Total data rate	0.251	0.473

In a third system (not illustrated) the secondary data is added to the 16 bit symbols output from the encoder 4 in such a way as to make the decoder 12 diagnose symbol erasures with a high degree of probability.

For example each of the 16 bit symbols in the first 10 symbol positions output by the encoder 4 could have 10 bits replaced with data from the secondary source and have the last 6 bit positions of the symbol set to all zeroes or all ones. This has the advantage that the RS decoder 14 need not have any prior knowledge of the multiplexing. The decoder 12 diagnoses the first 10 symbols as erased and switches the first 10 bits out. These can then be checked for coherence. Note that the chance of low level random noise causing the (16, 5) secondary code to declare all the first 10 symbols of each codeword as erased is remote.

It will be appreciated that it is not necessary for the symbols which are corrupted by the secondary data to be the first 10 symbols of each code word. RS codes are maximal distance seperable so that any symbol positions may be selected provided that the total number of symbols corrupted is less than the total redundancy. Pseudo-random selection of the symbols to be corrupted under the control of a key generator is a possible modification.

The described systems enable the data source S_2 to be switched in when interference levels on the communications channel 6 are relatively low and therefore the described communications system can be used more efficiently whilst still providing a high degree of integrity.

Switching in or out the additional data from source S_2 may be under the control of an operator or may be automatically controlled in dependence on a feedback signal from the receiver to the transmitter relating to the error levels in the received transmission.

CLAIMS

1. A communications system using a redundant code to encode and transmit data from a first source in blocks of data, and means for selectively multiplexing a proportion of data from a second source with each block of the encoded data from the first source, said proportion being less than the proportion of redundant data added to each block by the redundant coding.

2. A communications system as claimed in claim 1, which uses a Reed-Solomon code as the redundant code.

3. A communications system as claimed in claim 1 or 2, wherein the data from the second source is encoded before being multiplexed with the encoded data from the first source.

4. A communications system as claimed in any one of the preceding claims, wherein said multiplexing means comprises means for adding modulo 2 a bit of optionally encoded data from the second source with a bit from a block of the encoded data from the first source a predetermined number of times for each block so that the required proportion of the block has been multiplexed with bits from the second source.

5. A communications system as claimed in claim 1, 2 or 3, wherein said multiplexing means substitutes bits of data from the second source for corresponding bits in the encoded block up to the required proportion.

6. A communications system as claimed in any one of the preceding claims, further comprising means for encoding the output of the multiplexing means prior to transmission.

7. A communications system as claimed in claim 6, wherein the means for encoding the output of the multiplexing means uses a Reed-Muller code.

8. A communications system comprising a transmitter comprising an encoder for encoding digital data to be transmitted from a first source by means of a redundant code, means for selectively modifying predetermined bits or symbol positions of the blocks of encoded data output from the encoder in dependence on optionally encoded data from a second source to be transmitted, the number of bits from the second source being less than the number of redundant bits or symbols introduced by the encoder, and means for thereafter transmitting the encoded data blocks, and a receiver comprising means for separating the data from the first and second sources.

9. A communications system as claimed in claim 8, wherein the modifying means comprises switch means for controlling the input from the second source.

10. A communications system as claimed in claim 9, wherein said switch means is automatically controlled in dependence on a feed back signal from the receiver related to the error level or levels in the received transmission.

11. A communications system as claimed in any one of claims 8 to 10, wherein the selective modifying means comprises means for adding modulo 2 bits of optionally encoded data from the second source to bits of encoded data from the first source.

12. A communications system as claimed in claim 11, wherein the separating means comprises a decoder for outputting the decoded and corrected data from the first source and an error string of bits which are each set in dependence on whether there is an error in an associated bit or symbol in the received data block, and means for deriving from the bits of said error string corresponding to said predetermined bit or symbol positions the data transmitted from the second source.

13. A communications system as claimed in any one of Claims 8 to 10, wherein the selective modifying means comprises means for substituting optionally encoded data from the second source for predetermined bits or symbols of encoded data from the first source.

14. A communications system as claimed in any one of Claims 8 to 13, wherein the modified encoded data is further encoded prior to transmission.

15. A communications system substantially as herein described with reference to either Figure 1 or Figure 2 of the accompanying drawings.

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